Design for radiation protection of compact ERL in KEK

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Abstract

The energy recovery linac (ERL) is a promising candidate as a future X-ray light source. In KEK, a 3-GeV ERL facility is planned to be built as an X-ray light source [1]. Prior to the construction of the 3-GeV ERL facility, the new accelerator technology developed for the ERL is required to be demonstrated. Therefore, for the demonstration, a compact ERL was constructed at the ground level at the ERL test facility in KEK [2]. The compact ERL consists of parts of the injector and the recirculating loop. The commissioning of the injector was begun this April. Further commissioning of the entire compact ERL along with the recirculating loop is expected to begin this winter. In this paper, we present the shielding designs for the radiation of the compact ERL along with the measured results of field emission from the main superconducting cavities for the commissioning process.

Introduction

The KEK facility includes two light sources obtained from the PF-AR (6.5 GeV) and the PF ring (2.5 GeV) at the Photon Factory. A future light source at KEK is needed for driving cutting-edge scientific studies and future research at the Photon Factory. The 3-GeV energy recovery linac (ERL) at KEK is planned to be built as the proposed future light source. Before constructing the 3-GeV ERL facility, it is required to demonstrate the ERL technology. Therefore, in order to demonstrate the generation and recirculation of ultra-low emittance beams

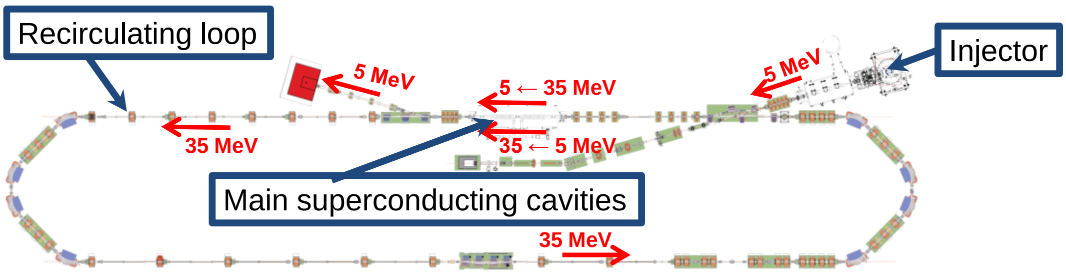

Fig. 1 Outline of electron acceleration in cERL.

in the ERL, we began to construct a compact ERL (cERL) that is operated at 35 MeV and 10 μA in the first phase.

The cERL consists of parts of the injector and recirculating loop, as shown in Fig. 1. The figure shows the outline of the electron acceleration scheme of the cERL in the first phase. Electrons are accelerated to 5 MeV in the injector part. The accelerated electrons are transferred to the recirculating loop and accelerated to 35 MeV by the main superconducting cavities. The 35-MeV electrons are transported round the recirculating loop till they again reach the main superconducting cavities. Subsequently, the electrons are decelerated to 5 MeV in the main superconducting cavities, and finally, they are brought to a stop in the beam dump.

The alignment of the cERL injector was completed on 4/11/2013. On 4/16/2013, the initial commissioning of the injector was begun. We expect the setup of the cERL injector to be completed on 5/23/2013, and subsequently, research operations will be begun. Further commissioning of the entire cERL along with the recirculating loop is expected to be begun this winter.

Expected loss in the main beam and shielding design of the cERL

The expected loss points for the main beam are indicated in Fig. 2. The energies, loss ratios, and loss current of the electron beam at the loss points are tabulated in Table 1. For the cERL, we constructed a 1.5-m-thick concrete wall shield + 1-m-thick concrete roof shield + local shield (Fe, Pb, and concrete) around the beam loss points on the basis of the floor space, expected beam loss ratios, and the results of the field emission measurements. The shielding design was validated by calculating the dose rate around the accelerator room using the MARS15 code [3]. Figure 3 shows an example of the dose rate distribution from beam loss at the collimator at the first arc (point e in Fig. 2) calculated using MARS15. The typical 1.5-m-thick concrete shield wall surrounding the cERL can also be seen in Fig. 3. The calculated dose rates from the beam losses at the outside of the shield wall were estimated to be less than 20 μSv/h, which is the dose rate limit in KEK.

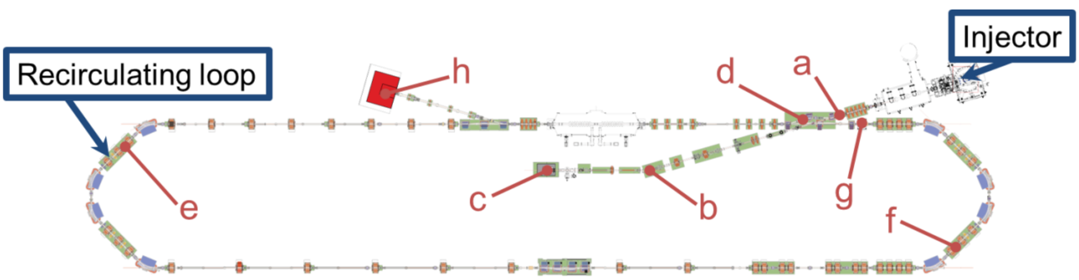

Fig. 2 Expected beam loss points of the main beam.

Table 1 Expected main beam losses.

Part	Symbol	Beam loss point	Energy (MeV)	Loss ratio (%)	Loss current (μA)	Current (μA)
	a	Collimator at Injector	5	0.1	0.01	10
Injector	b	Bending magnet at beam examination course	5	0.8	0.08	10
	c	Injector beam dump	5	100	10	10
	d	Collimator at the merger section	5	0.3	0.03	10
	e	Collimator at the first arc	35	0.1	0.01	10
Recirculating loop	f	Collimator at the second arc	35	0.1	0.01	10
	g	Movable Faraday cup for beam tuning	35	100	0.01	0.01
	h	Main beam dump	5	100	10	10

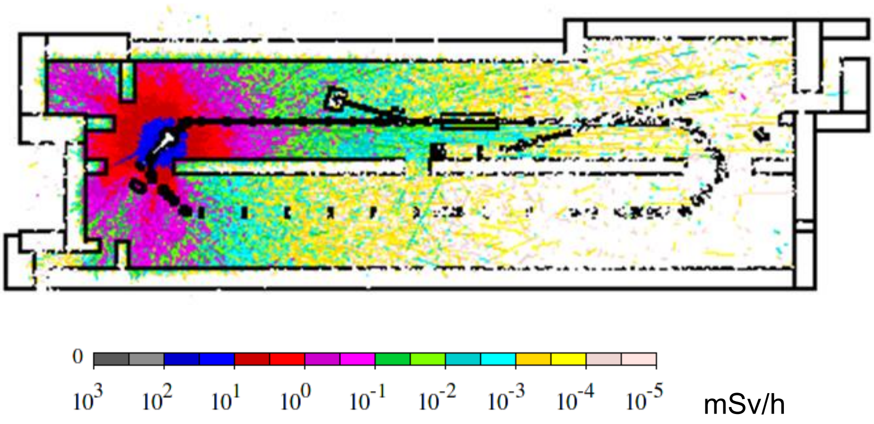

Fig. 3 Example of dose rate distribution calculated using MARS15.
In this calculation, the beam loss point is the collimator at the first arc (point e in Fig. 2)

Because the ERL involves the latest accelerator technology, the beam loss points and beam loss rate are actually unknown. These parameters will be investigated using the cERL. The results will influence the shield design for future upgrades (energy and intensity increases) of the cERL and the 3-GeV ERL facility.

Field emission from the main superconducting cavities

The cERL is equipped with a set of two main superconducting cavities (Cavity #3 and Cavity #4), as shown in Fig. 1. The energy of the field emission electrons from the main superconducting cavities depends on the location at which the electrons are generated and the voltage applied to the main superconducting cavities. Losses of the field emission electrons from the main superconducting cavities have to be considered as radiation production.

Therefore, we performed indirect measurements of the field emission current from each main superconducting cavity that will be used for the cERL. Our procedure for obtaining these measurements is listed below.

(1) The assembly of the main superconducting cavities was closed using SUS blind flanges.

(2) Voltage was applied to the single cavity.

(3) Dose rates from generated photons were measured at various locations around the cavity and on the roof of accelerator room using TLDs, ionization survey meters, and NaI survey meters.

(4) The dose rates per electron current were calculated using MARS15 for comparison with the measured dose rates in order to estimate the field emission current.

We found that the field emission currents corresponding to the applied voltages were different between Cavities #3 and Cavity #4. When the voltages applied to the cavities were increased, the field emission currents exceeded 0.3 μA at around 11.5 MV of applied voltage for Cavity #3 and 14 MV for Cavity #4. The field emission currents increased steeply with the applied voltage. Furthermore, the field emission current exceeded 1 μA at around 13.5 MV of applied voltage for Cavity #3 and 15.5 MV for Cavity #4.

Summary

Prior to the construction of the 3-GeV ERL facility, the cERL is being constructed at the ground level of the ERL test facility in KEK. For the cERL, we constructed a 1.5-m-thick concrete wall shield + 1-m-thick concrete roof shield + local shield (Fe, Pb, and concrete) around the beam loss points on the basis of the floor space, expected beam loss ratios, and results of the field emission measurements. The commissioning of the injector was begun this April. The next phase of commissioning of the entire cERL is expected to begin next winter. The field emission electron currents from the main superconducting cavities were measured indirectly. The field emission currents, which are larger than 1 μA, were measured at applied voltages of 13.5 MV for Cavity #3 and 15.5 MV for Cavity #4. The beam loss points and beam loss rates shall be investigated using the cERL. These results will be considered for the shield design for future upgrades (energy and intensity increases) of the cERL and 3-GeV ERL.

References

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